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Article

Stories and Theatre for Teaching Physics at Primary School

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Abstract: The paper contains progress reports supported by data about two short activities aimed at introducing physics themes in primary school. The first is a formal storytelling intervention named "Mommy Comet" carried out in first- and fifth-grade classes and concerning motion in the absence of forces in the Solar System broad context. The second is an informal work with third-, fourth- and fifth-degree students to investigate what physics is about. The results obtained by analyzing questionnaires and conducting interviews show how these narrative tools can offer wide potentialities and prove great effectiveness in introducing young students to physics.

Keywords: storytelling 1; scientific theatre; primary school

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1. Introduction

An essential prerequisite for any physics learning is motivation, which is a favorable attitude or a disposition of mind interested in approaching the discipline. Therefore, suitable methods to increase people's motivation are fundamental tools for teaching physics and, more generally, sciences. "In relation to the problems of motivation the average student is willing to learn what s/he considers useful, for her/his daily life and for what s/he believes her/his professional future may be, but, in a cost/benefit balance, the same student opposes a clear emotional refusal to study concepts, methods, analytical tools that involve great effort of understanding and whose usefulness are very little evident." [1].

A study, carried out ten years ago on a sample of about a thousand secondary school students in the province of Milan [2], shows some details concerning the image students have of physic. Although most students consider physics as an important resource for society [3], they usually consider it more linked to technology than to general culture [4]. Furthermore, it even seems that schooling acts in a negative way; in fact, the interest in physics fades over time, decreasing with the grade of class attended and reaching a lower level in scientific high school in comparison to other schools. Consequently, students who initially choose scientific studies often distance themselves from physics.

It seems that the problem is the way physics is presented at school, but it is not a new issue, since, "for decades there has been a line of research that is systematically confronted [...] with the evident difficulties of understanding and motivation of young people" [4]. This line of research has achieved remarkable results on which we can rely to improve teaching. Unfortunately, however, despite the many efforts made for years by the research community in physics education, the practical implementation of strategies and methods that come from didactic research encounters considerable difficulties (at least in Italy). This fact can be mainly ascribed both to school structure and the scarce importance given to teachers' basic education on Pedagogical Content Knowledge (PCK) [5].

The research has provided some clear results. To date, we know that the traditional structure of knowledge, as explained by school textbooks, does not represent the most effective scheme for learning: to foster and convey a deep understanding, a profound revision of the structure of the paths towards physical knowledge and a reflection on the didactic mediation is required [6]. Furthermore, in order to obtain a better and deeper understanding, significantly integrated into people's lives, the didactic proposals have (among other things) to highlight the modeling character of knowledge, clearly displaying physics specific ways of looking at the world and systematically comparing the complexity of concepts with the complexity of real facts. This aspect becomes even more important when we have to deal with children's education [7].

In order to be meaningful, the context from which ideas and physical descriptions gradually emerge must be rich. Contrary to what usually happens, the younger the students are, and the less trained in the discipline they are, the wider and less simplified the context has to be. Young children generally have a great motivation to explore the world; not for this, however, they should be considered as little scientists. In fact, curiosity for scientific phenomena is something different from the acquisition of structured scientific thought, and the latter must be learned and internalized in years of long work for which the school is the main road. In this context, we believe that a slow and progressive inquiry approach starting from the real non-idealized world of the context in which the child lives and studies can be of great help. Therefore, for example, the abstract definition of uniform accelerated motion makes sense only for students already equipped with a solid technical background, while the complexity of real movements that can be found in everyday life is much more suitable for young/novice students—differently from what is normally present in textbooks which, focused on simplifying as much as possible, debase the meaning of the discipline starting from situations that are too idealized. In fact, the abstract definition of acceleration only arises after a guided look at the world, not before.

An inquiry process that starts from the complex and general, as we have suggested, cannot help but highlight the modeling character of physics, and it is thus indispensable at school, but it is also important in informal contexts that can help physics become integrated into one's *weltanschauung* [8].

Insofar, proper education in scientific thinking must also be carried out on occasions that help link scholastic and formal educational experiences with non-formal and informal ones. In fact, scientific knowledge comes from experiences that can be proposed since childhood and subsequently evolve in a conceptual construction, always connected to the experiential phase, which, especially in primary school, cannot, however, take a rigid disciplinary framework yet. Experiences should, in general, be transversal, offering the opportunities of both performing and experimenting; on the contrary, too often in current teaching practice, they end up, instead—and even in primary school—in being too tied to the specific disciplines.

Teaching strategies cannot be, therefore, mainly based on concepts. The concepts are refined mental constructs that are often the final result of long elaboration, and there is no doubt that disciplines are the necessary structures to understand what concepts are and how they are coherently connected to each other in general theories [9]. However, it is not by strictly following this disciplinary structure that appropriate learning is obtained [6].

For example, while dealing with light, color and vision, we should avoid focusing only on geometric optics and also pay attention to discussing the formation of images and the sensations they generate. Sensations, in general, depend on the type of image, the light and the colors observed, the emotions they entail and the way we are allowed to express them. Similarly, when speaking of motion, we ought to experience both personal movement and motions of thrown or falling objects, experiences that are still connected even with the colors and sounds of the places in which they occur and to the emotions that are generated. It is thus clear that the context becomes multidisciplinary in a natural way, without any forcing [10].

When dealing with topics that are meaningful for people (since they are perceived as useful, beautiful or fascinating), interest, attention and the desire to understand are very often present. We have known for millennia that listening to stories together is one of the things that makes you feel good. Homer writes in the Odyssey that "there is no greater fulfillment of delight than when joy possesses a whole people, and banqueters in the halls listen to a minstrel as they sit in order due" [11].

Even a scientific explanation "is a story. It is a story about how some imagined entities, taken as real, would by their nature have acted together to produce the phenomenon to be explained" [12]. In fact, a very effective way to involve pupils in science is by exploiting storytelling since it has at least a double advantage. On the one hand, it attracts children's attention as soon as the story begins and keeps children completely focused on it [13]. On the other hand, the story constitutes a *fil rouge* along which scientific activities and imaginative thinking take place in a coherent ensemble in which the story alternates with the experiments, fostering an inquiry approach primarily to physics and sometimes even to the history of physics. At the same time, storytelling is also important for two other main reasons: the formation of hypothesis by means of figurative thinking (elicited by the use of fantasy, metaphors, rhythm and emotions) and the increase in motivation, or the stimulus in submitting questions (by means of imaginative thinking). The above explains why stories, especially those written and illustrated by, or with the help of, a physics education research group are a new field of research that inspires and guides scientific activities [14,15].

Another tool that is very close to storytelling is scientific theatre (see, for instance, the experience of the Milan Physics Education Research group [16]). Theatre can be extremely useful for promoting interactions between school, society and people [17]. In fact, it is able to develop scientific imagination, help improve learning thanks to emotional involvement, enhance personal needs and foster an approach to physics through affectivity. In this way, it also helps decrease cultural and gender gaps by promoting a scientific culture that is more profound and even more human [8,18]. Dramas and comedies feature a conflict that must be resolved by interacting with the other characters; this fact keeps the audience focused and responsive. If the conflict/game is turned into questions about physics, emotional involvement in the physics itself might arise, generating participation and active interest.

The EU has recently recognized theatre as a way to approach Inquiry-Based Science Education (IBSE) and to implement it in the classroom. For example, the "Teaching Inquiry with Mysteries Incorporated" project [19]—in which the Physics Department of the University of Milan participated together with 11 other European partners plus Israel—explored the direct use of theatre as a tool to bring teachers closer to IBSE. However, there is still a long way to go, and research on the use of theatre has only recently begun in physics education.

Both storytelling and scientific theater are tools that can be used in a formal or an informal context. Below, we illustrate two examples designed and developed by the Research Unit in Physics Education of the University of Milan aimed at introducing some aspects of physics in primary school: the first through stories in a formal context and the second through scientific theatre in an informal one.

2. Mommy Comet—A Story for Primary School

"Mommy Comet" is a pilot educational project dedicated to primary school, which aims to bring children closer to physics by introducing the basic elements of motion. In fact, motion represents an important part of children's daily existence, yet its study is particularly difficult both because its description depends on the frame of reference and because of its dependence on time which makes the description complicated. Storytelling was the tool explored to try to overcome these difficulties.

We here describe experimentation of a story-based Teaching–Learning Sequence (TLS) designed by the late Sara Barbieri and myself, with the aim to introduce the notion of "free falling" in primary school [20,21].

2.1. Materials and Methods

The educational path was divided into three lessons of two hours each that were held by Sara Barbieri and the author of this paper in the presence of the class teacher in a primary school near the Como Lake (Italy), consisting of three lessons of two hours each.

The first experimentation involved 50 first-grade children and the second 53 fifth-grade students. All class interventions were recorded and transcribed by a graduate student.

The lessons were introduced by six short stories specifically written and illustrated for this project. The reading of the stories defined the times, attracted the attention of the children and served as the structure within which the physics of motion was introduced, both through experiments carried out in the classroom and through outdoor laboratory and games activities. The illustrations of the stories and the photos were also important, which were projected in the classroom during the reading and helped children fit into the atmosphere of the story and visualize physical situations that they may have not yet experienced.

The story tells of a primary school child who lives a fantastic adventure that will take him up to L2, the second Lagrangian point, from which he will observe the motions of the planets of the solar system and of the comets arriving from the Oort cloud. The choice to contextualize motion in the field of astronomy is primarily due to the fascination that stars and planets exert on children and to the fact that the solar system is one of the usual subjects of teaching in an Italian primary school.

The approach concentrated on the physics of the motion concentrated on the description of motions that are, at the same time, simple and meaningful for children.

Straight uniform motion is not significant for them, while freely running is not reproducible. We, therefore, decided to use the motion of thrown objects (balls, etc.) as the "natural" motion of bodies since they allowed a simple description in the conceptual framework of general relativity.

The purpose was to avoid starting from the principle of inertia, studying trajectories and motions of falling objects instead, as if they were natural, free of force motions. In Newtonian mechanics, forces do not "remain" in the object upon which the force is applied. In the absence of forces and disengaging from the established tradition of attributing motion of bodies to gravity, from our point of view, once let alone or thrown, objects simply fall. The previous sentence cannot and must not be taken literally: air resistance, Coriolis' force and Archimedes' thrust change this simple description and must be discussed, but, quite obviously, without necessarily arriving at a formal expression for them. Hence, in this approach, we did not introduce the force of gravity in a way similar to what is performed in general relativity; this means, for instance, that an object that is orbiting around the Earth, such a spacecraft, is not subjected to a force.

The work that, from the didactic point of view, was very significant in the development of this TLS consisted precisely in the operation of "how removing" everything that prevented us from grasping and recognizing the elliptical motion as the natural motion of a body in free fall.

What has been "removed", however, had to be first explicitly appreciated as a constitutive part of an extremely complex and interesting world. The children thus passed through the colors of the sky, the floating of the clouds, the flight of birds and airplanes and the study of day and night in relation to the position of Earth and Sun by means of experiments and games made in the classroom. Little by little, children were able to put in the same category the motion of the Moon around the Earth and the motion of a ball thrown to a friend. The elliptical trajectory thus became the unifying form of the motion of bodies in free fall.

Due to the children's known difficulties in considering reference frames different from the ground, we decided to start introducing the concept of trajectory right in the reference frame of their classroom and, only later, to consider further possibilities. We observed that the physics of free-falling objects in a fixed reference frame has many general features that are suitable for children: it can be intelligibly and clearly stated; its phenomenology can be (at least in part) hands- and minds-on; it may be very easily experienced and it has a clear connection with body movement—a fact that can greatly help to understand [20].

There were three research questions:

Research Questions 1 (RQ1). *Can a short-story approach, within a very wide and imaginative context, be an effective choice to face and overcome some well-known difficulties about basic notions on motion in primary school?*

Research Questions 2 (RQ2). *What can we say about children's learning on the concepts of trajectory and the idea of free-falling motion?*

Research Questions 3 (RQ3). *Are there differences between the responses of the first- and fifth-grade children? Which ones?*

Lessons were similarly structured in both grades. By exploiting the use of metaphors, the stories introduced an argument, but the narration was stopped in some crucial moments to allow students to give their opinion on what would have happened next or perform experiments and activities specifically designed to explore a topic.

We faced two disciplinary knots: (1) the notion of trajectory and (2) the way free (i.e., without a force) objects move. Our *fil rouge* to untie these knots was a simple, but not trivial, observation that helps unify and obtain coherence to a large mass of phenomena: each body falls with an elliptical path towards another body with spherical symmetry (a thrown stone on the Earth, a satellite around the Earth, a planet around the Sun, and so on).

The path covered the following aspects: (1) trajectories of jumping children and of moving objects; (2) dropping a ball and throwing a ball; (3) dropping and throwing pieces of paper of different shapes (to understand the role of the air); (4) falling and floating objects in water (similar clouds in the air of the atmosphere) (Figure 1); (5) from a free-falling object to a forced flying object (birds and airplanes); (6) sky colors and light colors (dispersion by a prism); (7) diffusion by small particles; (8) blue sky and sunset (Figure 2); (9) the Earth is round (how to use a globe; see the "globo local" project (http://www.globolocal.net/eng/download/International%20Globo%20Local%20Project.pdf) (accessed on 21 September 2021); day and night; (10) the Lagrangian point L2: a trip into to the solar system; (11) astra and the days of the week; (12) comets. Here, we briefly provide a quick look at only the activities ((1) and (2)) that were the object of our research. We hope they will be enough to obtain an idea of the type of approach and work.

Figure 1. Children performing experiments about floating objects. A globe can be seen refracted by the water.

In the classroom, we started reading the first story. As already mentioned, while reading, drawings and pictures illustrating the story were projected on a screen.

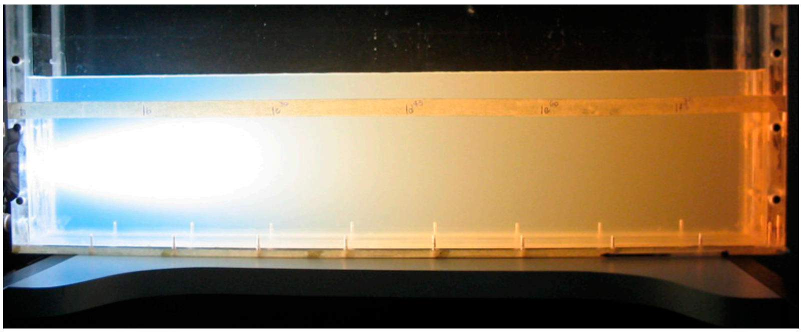


Figure 2. Diffusion of white light by small silica particles in water.

> *"Claudio is a child like many others, perhaps a little chubby, maybe every now and then his tongue stumbles and words do not come out as easily as he would like. Claudio perhaps blushes when in class the teacher asks him to read. Oh, yes. But this afternoon Claudio is also worried more than usual about the upcoming sport competition that will be held the next day at school.* [...]
>
> *Claudio is going to spend the whole afternoon studying...*

(Figure 3)

Figure 3. Claudio is going to spend the whole afternoon studying. Drawing by Sara Barbieri.

> *But how?! I mean: would it not be better if he exercised a little bit in jumping? But he is studying. He is browsing without stopping his books, trying to understand what animals are able to do long jumps. After studying, he also begins to work in order to turn a pair of sneakers in a couple of kalofrogillo.*

(Figure 4)

Figure 4. *He also begins to work in order to turn a pair of sneakers in a couple of kalofrogillo*. Drawing by Sara Barbieri.

> *That's how Claudio named his invention, which contains the secrets of the jumps of kangaroo, locust, frog and nine-banded armadillo.*

> [...] *"Let Claudio prepare for the first jump!"* [...] *Claudio's heart beats so hard that it seems to jump out of his chest; excited and upside down, he does not remember kalofrogillo anymore and gets ready on the starting line, takes a running start, lifts off the ground and* (Figure 5.)*... pof! While Claudio was jumping, his back was designing a curve in the air, but from the point of departure to the arrival point, only... One meter twenty . . . short!"*.

Figure 5. *Claudio takes a running start, lifts off the ground and...* Drawing by Sara Barbieri.

At this point, the story was stopped, and children were asked to draw a picture answering the question: "Which line has been drawn by Claudio's back in the air?". Once we collected the drawings, we started filming the motion of various objects that were first let free to fall and then thrown in the air with an initial velocity different from zero. Videos of some children making long jumps were also made. We discussed the notion of trajectory and the fact that each body is falling with an elliptical path towards another body (Figure 6).

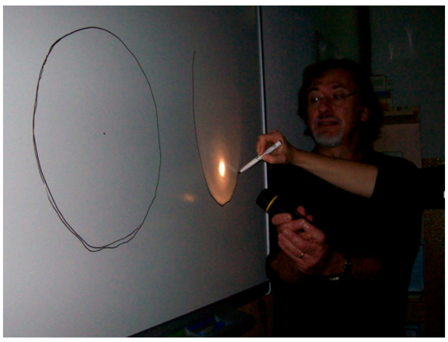


Figure 6. The author and Sara Barbieri are drawing an ellipse as a conic.

In this context, even the usual parabolic motion of objects on Earth is seen as a first approximation of an ellipse with one of the foci in the center of the planet (Figure 7).

All the drawings and the written previsions made by children were collected. We also collected many photos and videos of children's activities, but they are not shown here for privacy reasons.

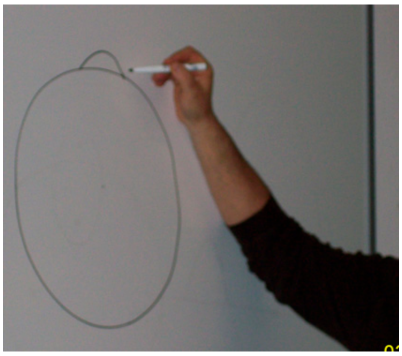


Figure 7. The path of falling objects near the Earth.

2.2. Results

Six weeks after the class interventions, a test was given to first- and fifth-grade students. For what concerns this paper, we referred only to some of the questions related to activities (1) and (2) that were given to students separately.

Question 1 (Q1). *Draw the trajectory of a small weight fastened to a thread, from when Sara lets it go to when Marco stops it. (Experiment performed in front of the students during the test).*

Question 2 (Q2). *Draw the trajectory of the ant Petrilla going out of her anthill, climbing up a rock and then returning to where she started. (This is an imagined situation).*

Question 3 (Q3). *Draw the trajectory of an object that, after you let it go, has a part of an ellipse as a trajectory. What object is it? What has set the object in motion?*

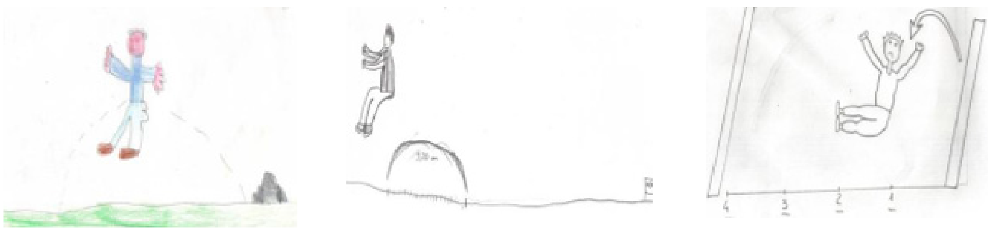
Question 4 (Q4). *Marco is throwing a ball into the hula-hoop. Draw its trajectory. (Experiment performed in front of the students during the test).*

Question 5 (Q5). *In your opinion, which of the ellipsis drawn in the following figures is the one that completes the trajectory? The large circle is the Earth; inside the rectangle, you see the trajectory of the ball going into the hula-hoop (Figure 8).*

Figure 8. Which of the ellipsis drawn in the following figures is the one that completes the trajectory?

Drawings made during class interventions by the children of the first and the fifth grade are different. While the former is full of colors and details, the latter are monochrome and much more schematic. Moreover, in fifth-grade drawings, the trajectory is often depicted separated from the body and sometimes resembles a comic-strip story (Figure 9).

Answers to questions Q1–Q5 are schematically reported in the following self-explanatory Table 1.



(**a**) (**b**) (**c**)

Figure 9. (**a**) A typical drawing of a first-grade child; (**b**) A typical drawing of a fifth-grade child; (**c**) A cartoon-like drawing of a fifth-grade child.

Table 1. Answers to questions Q1–Q5 given to 48 1st-grade students and to 46 of the 5th-grade.

Q1-Q1	**Both right**	**Wrong**	**Cartoon-like**	**Displacement**	**Only one way motion (non back and forth)**	
1st gr.	27	3	2	8	8	
5th gr.	32	1	3	3	7	
Q3	**Right**	**Wrong**	**Ambigous**	**Impossible**	**No drawings**	**No explanations**
1st gr.	9	15	1	6	7	5
5th gr.	27	9	3	0	0	0
Q4	**Right**	**Wrong**	**Ambigous**	**Impossible**	**No drawings**	
1st gr.	32	4	0	0	2	
5th gr.	27	6	4	0	1	
Q5	**(a) (correct)**	**(b)**	**(c)**		**(d)**	
1st gr.	3	22	4		4	
5th gr.	20	13	3		1	

3. Under Another Light—A Scientific Theatre Play for Children

"Facciamo luce sulla materia" (Let's Throw Light on Matter) and its development "Sotto un'altra luce" (Under Another Light) are theatre plays for 3rd–5th-grade students, designed and performed by Marina Carpineti, Nicola Ludwig and the author of this paper, developed by the University of Milan, in collaboration with "Teatro del Sole" and "Compagnia del Sole", respectively. Both plays are set in an imaginary physics laboratory where three scientists carry out more than 30 experiments on the state of matter and light. To date (August 2021), they reached about 300 replicas [22].

3.1. Materials and Methods

At the end of the show, children were invited to ask questions for about twenty minutes. Then they were asked to send us drawings of what they liked most. The answers to questions asked at the end of the shows—plentiful, smart and interesting—clearly show how enthusiastic their participation was, and it seemed almost incredible that on more than 200 different questions asked, all of them—except one: "were there real scientists or actors on stage?" —were related to physics!

About 15% of the questions concerned the states of matter ("what state do pudding or foam belong to?" or "does ice melt in cold or hot water?" . . .). Another 20% of the questions concerned liquid nitrogen and its properties "when you put a balloon inside that blue container (a vacuum flask/Dewar bottle), why does it flatten out?"), "why does liquid nitrogen not get wet around when it is spilled over?"). Twelve percent of the questions were related to the vision with a thermal camera; 11% were about polarizers. The remaining questions concerned light and colors: diffusion, reflection, mirrors, refraction, shades, inks and prisms.

A questionnaire was also submitted to teachers during the performances to establish the efficacy of the initiative.

The context is completely informal, and no agreement is, in general, previously made with schools to make connections with the teaching program. Therefore, the analysis briefly described below was aimed only at evaluating the effect of the show on children's imagination in terms of physics learning and not about specific topics.

It was carried out by one of our undergraduates completely unrelated to the show to prevent teachers from preparing the children in any way before the interview. Our collaborator was able to:

1. Conduct a 45-minute interview with 54 primary school classes, 26 of whom attended the show in the same year of the research, 13 in the previous year and 18 (control group) did not see the show at all;
2. Catalogue nearly 500 drawings, randomly chosen among the thousands sent to us by children;
3. Analyze the questionnaires given to the teachers.

3.2. Result

Interviews were held, according to the availability of schools and teachers, both with classes that saw the show during the previous or the current school year and with classes that did not. The interviews were prepared by the Physics Education Reasearch group of the University of Milan with the help of a pedagogist (Graziano Cavallini) to directly verify if the show had left any memories in the children. Therefore, it was decided to compare a group of classes that had seen the show with another sample of classes that had not (control group). The meetings with the children had variable durations, depending on the availability of the class teacher and the ability to concentrate on the children, from a minimum of 30 min to a maximum of 45 [16].

In order to have answers that were as spontaneous as possible and not distorted by induced memories, the request to interview the classes was made months after having seen the show and without making any reference to it so that children could not be influenced or prepared.

From the analysis of the interviews, we wanted to obtain a statistic of answers to the following questions.

Only for those who have seen the show: Is the show remembered? Yes/No. In the case Yes: is the memory spontaneous or not?

For all classes: Do children at least roughly know what physics is about? Yes spontaneously/No. Do they connect the work of a physicist, or of a more generic scientist, to the show? Yes spontaneously/Yes with suggestions/No. Do children know what the work of a physicist is about? Yes, making direct references to the show/Yes but generically with other arguments/No. What were the possible references to the show about? Matter, light, colors?

During the interviews, the memory of the show was never directly and explicitly stimulated: children themselves had to connect the somewhat generic question posed with what they had seen.

In the listening and recording phase of what children remembered, one child at a time began to speak, taking a cue from what a companion was saying and correcting them or pointing out what they said. Regarding counting children with memories of the show, only the interventions that could be considered as a clear signal of a memory of the experiment under consideration were counted. Similarly, since in many classes some children started speaking of an experiment previously already described by another classmate (out of distraction or out of the desire to tell what they remembered), the experiment was counted among those memorized by the child only if its description appeared sufficiently clear and differentiated from the one made by the classmate.

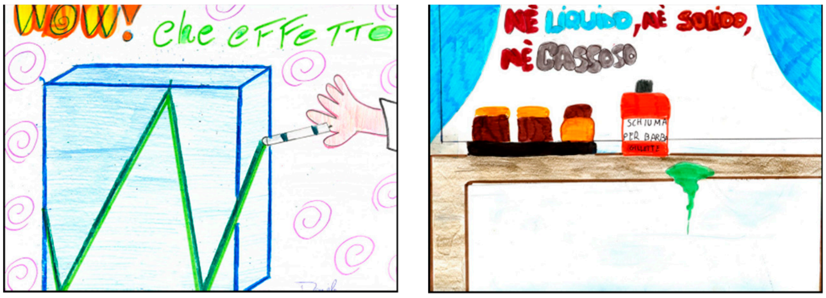
The interviews highlighted that children had many articulate memories that came out in more than 70% of pupils of the classes that had seen the play in the same year of the research and in more than 40% of pupils of the classes that had seen the play the year before.

Over 80% of the classes that had participated gave clear answers to the question "what do physicists study?". Examples of answers were: "they do experiments", "they study the colors that make up white", "they do experiments with liquid nitrogen . . . that is very cold", "what light is able to do in water . . . ", all containing evident references to the experiments made in the performance.

It must be highlighted that pupils who had not seen the show gave very different answers to the same questions. Here are some examples: "Physicists study physical education, the body, the organs", "they do experiments on chemicals", a physicist " . . .

is an astrologist" or even "a lunar scientist", with the percentage of "correct" answers decreasing to 20%.

Moreover, drawings that faithfully depicted the show were made by pupils with very refined details (Figure 10).



(**a**) (**b**)

Figure 10. (**a**) A green laser beam enters a transparent tank containing water and silica nanospheres to increase diffusion and visibility (drawing made by a 9-year-old child); (**b**) Is shaving foam liquid or solid or gas? (drawing made a 10-year-old child).

Some experiments particularly caught the children's attention, and those that were most frequently drawn were the ones that raised most children's questions. Some differences in representation were probably due to the difficulty of drawing the subject. For example, the properties of viscous-elastic material are extremely difficult to be depicted in a static context.

Concerning the questionnaire submitted to the teachers, 98% of the teachers believed that the contents of the show had a strong connection with the school program and, among them, 90% considered the show very useful as a teaching aid.

Nearly 45% of the teachers said that most of their students spontaneously talked about the show in the first week after the play. Children's interest was scored "high" by more than 50% of the teachers and "good" by more than 45% of them. Moreover, we also received the request for more material and suggestions for classroom work from teachers.

Concerning the questionnaire given to the teachers, we can say that most of the teachers (about 250 teachers out of nearly 300) answered, and it was thus possible also to have feedback from the teachers' point of view. Here, we only report three questions together with their answers, directly related to what we are discussing.

1. Have the contents presented during the show clear connections with the didactic program carried out in the class? No 2%, Yes 98%;
2. If your previous answer is yes, do you think the show was a useful teaching aid? No 0%, Somewhat 10%, A lot 90%;
3. In the first week following the show, how many children spontaneously talked about the show? Nearly all: 43%, more than a half 13%, 5 to 10: 21%, 3 to 5: 6%; 1 to 2: 17%.

4. Discussion

The data regarding the use of the Mommy Comet story, albeit partial, show, in our opinion, the importance and the effectiveness of the use of storytelling in primary school. The involvement of the students in a few hours of work led to results that a priori seemed almost impossible to achieve. Concerning the idea of trajectory, for example, before classroom intervention, teachers found it extremely unlikely that the concept of trajectory could be understood by pupils without previously giving a formal definition of it. Moreover, they believed that placing the discourse in a context as broad as that of the Solar System would have been dispersive and ineffective, just as taking into account "irrelevant" perceptions such as those relating to sounds, colors, etc.

The results, in our opinion, are also clearly positive for what regards the idea and the understanding of what an ellipse is (for example, its difference from the profile of a flattened oval, similar t that of an egg, has been clearly highlighted by the children when answering the question: What is it like? What is it different from?).

With increasing student age, we observed the transition from a pictorial representation to a more abstract one, as could have been expected, and also an attempt to answer the alleged teachers' requests in a more "suitable" way. From the results of the test, we could conclude that the conception of trajectory is quite clear for both six-year-old and ten-year-old children, but that they manifest their thinking in different ways.

The younger ones are in fact more accurate, but, in general, have more difficulties in describing what they do not see. Most of them are very realistic in describing what they see. Some, on the contrary, turn out to be very abstract, confusing the trajectory with the displacement and thus giving the wrong answer but showing that they might have internalized a more elaborate concept.

As for the elliptical motion of a thrown object, class discussions, homework and drawings make us think that the idea of trajectory can also be transmitted without giving the concept a formal definition; the same can be said of the term ellipse. The answers to the fifth question show, however, that the details of the elliptical trajectory were not as well understood as the overall concept. In particular, in their answers, first-class students tend to focus on a more symmetrical but incorrect trajectory.

Ten-year-old children are less accurate but more "dynamic": many of them tend to represent motion in a schematic but communicative way, with cartoon-like drawings adding arcs to the lines of their trajectories. Forty percent were able to represent, at least to some extent, the meaning of the elliptical motion of thrown objects.

Concerning the effectiveness of the scientific theatre in an informal context, we observed that the play we offered, lasting about an hour, led to almost correct imagery of what physics is about as a discipline: an unexpected result that mainly came out from questions at the end of the show. In fact, they concerned issues that were not dealt with at all during the show, such as electricity, the Polar Aurora or floating; themes, however, which certainly belong to the field of physics. However, the children did not ask questions about animals that (for example of bees) we talked about in the show while describing polarization or about chemistry. It seemed as if the physical discipline found its place and its areas in an almost natural way. Of course, these are only hypotheses and should be validated with further research.

5. Conclusions

Storytelling is a very important tool in children's education because it stimulates the formation of a hypothesis, raises motivation and gives children the occasion to wonder and ask questions. With storytelling, children are free to use their imaginations and emotions. Our "Mommy Comet" short stories are like a train that carries children from the Earth to the Oort cloud and are the core of our approach to the mechanics and the Solar System for primary school. The key point is a simplified but unified sketch of all celestial motions: each body is falling with an elliptical path towards another body. The simplicity of this observation is the *fil rouge* that hopefully makes celestial orbits closer and more meaningful to children's lives and thoughts: the first step for a thing to be felt alive and relevant.

Teachers can use ready-made stories or can develop new tales by themselves, thus potentiating their stimulating and engaging effects. In this last case, in fact, teachers would become more aware of the conceptual knots involved and also more enthusiastic. However, for this aim to be achieved, a profound revision of teacher formation is needed.

Concerning scientific theatre, theatrical representations and rites are very ancient and have always played a didactic role, passing down to young people the mythological and cultural heritage and, often, also the rules of moral behavior.

In its 17 years of activity, the group "Lo Spettacolo della Fisica" (Marina Carpineti, Marco Giliberti and Nicola Ludwig) of the University of Milan wrote and performed eight shows with more than 400 performances and 130,000 spectators and 3 "augmented lectures", which are spectacular lessons.

The strategy has always been to write and perform real theatrical performances, with scientific experiments within a dramaturgy (not a sequence of experiments) with reflections on the role and the meaning of physics, trying to bridge the gap between formal, non-formal, and informal education. The results show that the dramatization of scientific learning through various means that encourage social interaction, improvisation and reflection on historical themes is effective not only in engaging and motivating students but also in helping them grasp more inspiring conceptual and procedural ideas. At the same time and of equal importance, it also helps teachers understand what students think [23].

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